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VIII.

FURTHER OBSERVATIONS UPON THE OCCURRENCE OF DIAMONDS IN METEORITES.

By Oliver Whipple Huntington, Ph. D.

Presented October 11, 1893.

Ever since Haidinger, in 1846, described a cubic form of graphite in the Arva iron, and Rose suggested that the crystals were pseudomorph after diamond,* the possibility of finding the gem itself in meteorites has been conceived.

In 1886, H. Carvill Lewis, after his study of material from the greatest depths of the South African diamond mines, predicted the discovery of diamonds in meteorites.† Hence it was no great surprise when graphite having the hardness and form of the diamond was found by Jerofeieff and Latschinoff in the Novo Urei meteorite.‡ No colorless material, however, seems to have been found till E. Weinschenk described, in 1889, a minute quantity of transparent grains from the Arva iron, hard enough to scratch the ruby, and burning in oxygen to form carbonic acid gas.§

A fresh interest was added to the study of the subject two years ago when Dr. A. E. Foote brought numerous pieces of the Cañon Diablo iron from Arizona, and Professor Koenig of Philadelphia announced that a piece of it contained diamonds, his statement being based upon the appearance of a black vitreous substance lining a cavity, and having a hardness beyond the sapphire. Dr. Foote says in his paper on the subject, "The most interesting feature is the discovery for the first time of diamonds in meteoric iron." ‖ He then refers to the cubic

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* Pogg. Ann., Bd. LXVII. pp. 437–439, 1846.

† British Association, 1886, p. 667.

‡ Verhandl. der kais. russ. Mineral. Gesellschaft, 2d Series, Vol. XXIV. p. 263, 1888.

§ Annalen des k.-k. naturhistorischen Hofmuseums, Vol IV. p. 93, 1889.

‖ Proceedings of the American Association for the Advancement of Science, Vol. XL. p. 4.

PLATE I.

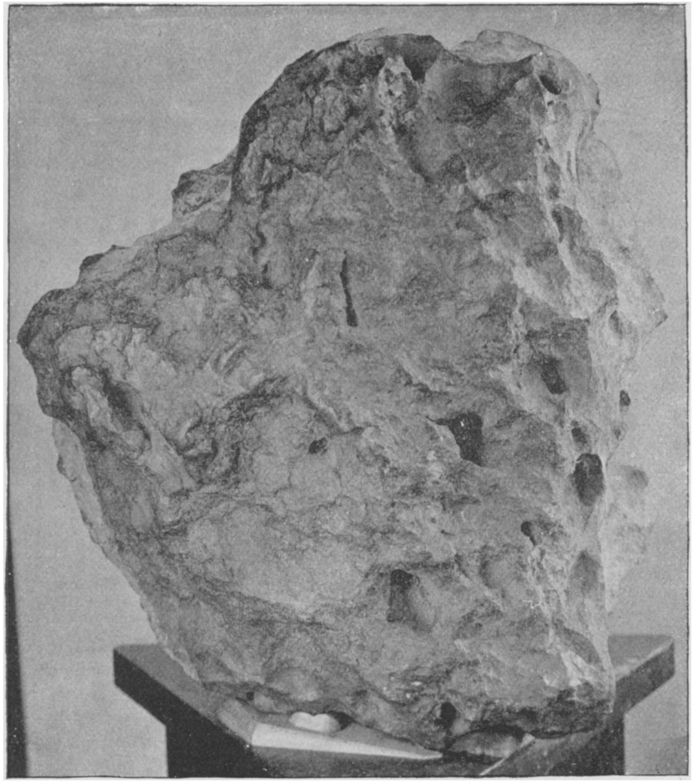

Fig. 1. — Front View.

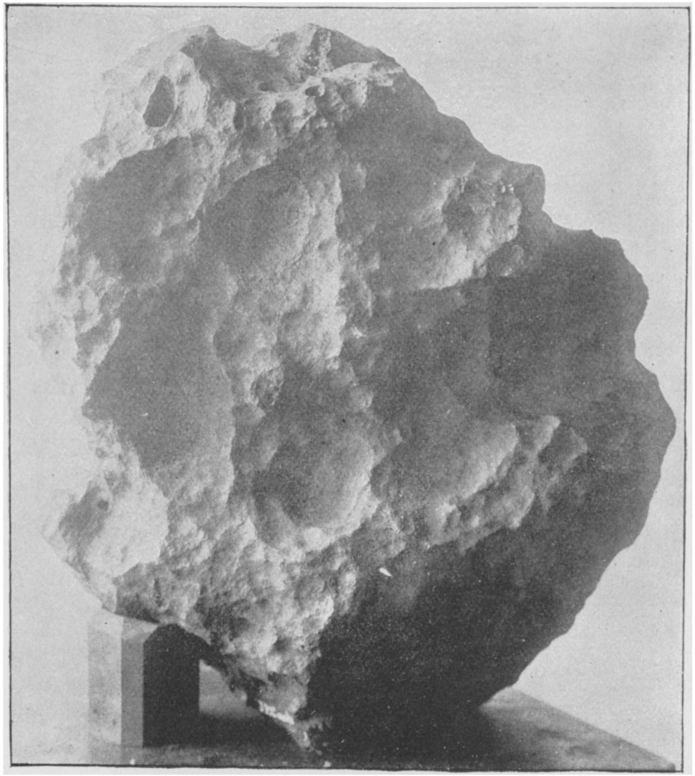

Fig. 2. — Back View.

Cañon Diablo Iron — Weight, 1087 pounds.

Actual Size.
Height, 25 inches.
Breadth, 23 "
Thickness, 15 "

form of graphite in the Arva iron, described so long ago by Haidinger, and the cliftonite found by Fletcher in the Youndegin iron, but makes no mention of Weinschenk's description of colorless transparent diamonds in the Arva iron.

The Mineral Cabinet of Harvard University was presented, through the liberality of Francis Bartlett, Esq., with one of the original masses of the Cañon Diablo meteorite, and it was at once examined for diamonds. A piece weighing one hundred grams was dissolved in acid, and, after the usual process of getting rid of the carbon, silica, etc., a small quantity of fine powder was separated by its higher specific gravity and examined under the microscope. It appeared to be made up of dark and light grains, the latter showing unmistakably the lustre of the diamond. The colorless particles were separated mechanically upon the stage of the microscope, and looked to the eye like white beach sand. One of these grains was mounted in the point of a metallic lead pencil, and it was found that, though so small, it would readily cut glass with the characteristic singing noise of a glass-cutter's diamond, and it would also readily mark upon a polished sapphire. There was not enough of the clear material obtained at the time for a chemical test, and on accouut of the association of the diamond grains with amorphous carbon, such a test would not have been conclusive without a perfect mechanical separation.

This seemed at the time sufficient proof that the material was diamond, and a portion of it was exhibited before the meeting of the American Academy of Arts and Sciences on May 11, 1892, and at that time the author showed a large nodule of graphite from the Sevier County iron and said: —

" As is well known, graphite separates from melted cast iron when it slowly cools, and the connection of these masses with the iron meteorites indicates that they also were formed by the slow cooling of masses of melted iron, very possibly thrown up by volcanic action from the interior of some planet. The high specific gravity of the earth suggests the conjecture that its interior is a mass of iron, and the metallic iron which has been found in the deep-seated eruptive rocks, as in Greenland and the South of France, gives support to the hypothesis that these rocks may be the matrix of the diamond, and that the diamond crystals may have separated during slow cooling from the melted metal forced up from below.

" Thus: —

" Graphite separates out from meteoric iron. It also separates during the cooling of cast iron.

"Graphite is further found associated with the iron of the deep-seated rocks.

"Graphite, crystallizing in the form of diamond, is found in meteoric iron. Diamonds are also found in meteoric iron.

"The greatest deposits of native diamonds appear to have come from great depths.

"Does it not appear plain that the meteoric diamonds, which are obviously in their original matrix, may explain the origin of the terrestrial diamonds?

"My object has been merely to point out a possible relation, and not to advocate a theory, but in this relation we have a clue which may possibly lead to a solution of one of the most obscure problems of mineralogy."

It was further suggested that pressure might be a determining factor in the crystallization of carbon. At the time this seemed a somewhat large assumption to make from so small data, but since then M. Moissan has followed up the same idea by most interesting experiments, in which he finds that carbon can be made to crystallize out of melted wrought iron in the form of diamond if the iron is allowed to cool under pressure; as is the case when the melted metal expands in setting against the crust formed by quenching the exterior of the mass with water.* May it not be that, if we could reach thus a pressure commensurate with that produced by the crust of the earth, the resulting diamonds would attain the size and perfection of those now found in the famous diamond fields of South Africa?

In December, 1892, M. C. Friedel,† apparently not having seen the papers published by the author seven months before, made a thorough examination of some of the Cañon Diablo iron. The diamonds that he isolated were of the carbonado variety, and in order finally to prove that the black grains were diamond he burnt a portion in oxygen. Thus he proved chemically that the substance was carbon, and since the hardness was beyond the ruby he considered it sufficiently determined that it belonged to the variety diamond. The proof of the hardness of the diamond, however, does not rest with the fact that diamonds will scratch the sapphire or the ruby, since this may be done by other substances, notably "carborundum," but diamond alone will cut diamond, and this test had not been applied to the material from the Arva, Novo Urei, or Cañon Diablo meteorites. Especially since the work of Daubrée and others has shown how numerous the allotropic forms of carbon may be, varying in hardness, specific gravity, aud other physicial characters, it seemed of value to get a more accurate determination of the hardness of this new material, since no distinct crystals had been observed.

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* Comptes Rendus, Tome CXVI. No. 6, Feb. 6, 1893, p. 218.

† Bulletin de la Société Française de Minéralogie, Tome XV. No. 9, December, 1892, p. 258.

At the suggestion of Mr. George F. Kunz, the author undertook to dissolve many pounds of the Cañon Diablo iron, in order to obtain enough diamond dust to use at the Columbian Exhibition for cutting and polishing rough diamonds, thus demonstrating in a practical way the fact that we have true diamonds in meteorites.

A method of dissolving iron slightly different from that described by the author in "Science"* was adopted, in order to find if possible the paragenesis of the diamond material. About two hundred pounds of the iron was examined, and the most promising pieces were dissolved. The object of working on so large a scale was twofold. In the first place, to obtain sufficient material for the practical test of cutting and polishing rough diamonds, and in the second place to discover how the substance occurred, and whether it crystallized in the usual form. Of course there was also a possibility, though not a probability, of happening upon a crystal of considerable size. The specimens of iron selected were successively suspended by a platinum wire in a platinum bowl, filled with hydrochloric acid nearly saturated with chloride of iron and then slightly diluted with water. The iron was made the positive pole of a battery consisting of twelve gravity cells, the bowl forming the other electrode. When the conductivity of the solution was properly adjusted by means of the chloride of iron it was found that only the pure iron of the meteorite would dissolve, thus setting free the plates of schreiberseit and taenite, as well as the graphite and other impurities, bringing out the crystalline structure of the meteorite in wonderful perfection.

A partially dissolved piece is shown a little less than the natural size in Figure 1. Unfortunately, the sketch does not bring out the plates as prominently as they appear in the specimen, and the differences of tint, which are very striking in the original, cannot be reproduced in a black and white print. If the acid was too strong, or the temperature of the solution slightly increased, all the distinction of parts at once disappeared, and it dissolved *en masse*, leaving a great quantity of slime in the bottom of the dish.

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* Vol. XX. No. 492, July 8, 1892.

The iron was dissolved in two- or three-ounce pieces, and it at once appeared that there was a wide variation in its composition. Most of it contained no diamonds whatever. One piece, however, in the process of dissolving showed an irregular vein running through it consisting of a white vitreous substance varying in width from a fine line to nearly four millimeters. On trying the hardness of the vein-stuff, it was found to be beyond the ruby. On further examination, it appeared to be a mixture of iron, a sulphide of iron, silica, amorphous carbon, and diamond, so that it finally had to be crushed in order to get rid of all the iron.

The hardest grains were isolated by the method described in the previous papers, and when examined under the microscope one minute but perfect octahedron of diamond was found, transparent and colorless. It was separately mounted on a microscope slide, but soon disappeared, and in its place were found only some very minute angular fragments. A second crystal was afterwards isolated, but disappeared in like manner, suggesting that they had been formed under pressure, and when exposed in a warm room had exploded.

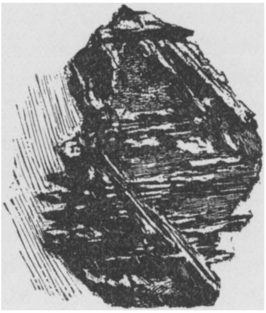

FIG. 1.

This called to mind the fact that broken diamonds are so often found in the South African mines, though the cases may not be analogous, since in the latter instance the fragments have never been found associated.

About half a carat of diamond powder was finally obtained, being separated by its specific gravity from a very large quantity of amorphous carbon. The particles varied from colorless through yellow and blue to black. Many of them appeared to be angular fragments, though some of them looked not unlike hyalite except for their more brilliant lustre. Several perfect little octahedrons were found that did not break up, and Figure 2 is an exact reproduction of a drawing of one of these crystals, traced through a camera lucida attached to a microscope. The original specimen measured only a little over a hundredth of an inch in diameter, but viewed through a two-thirds objective it showed distinctly the hexakis octahedral planes, the curved edges, striations, etc. exactly as seen in the drawing. Unfortunately, the print cannot show the adamantine lustre and clear water of the crystal.

A portion of the powder was sent to Mr. Kunz for the diamond-cutting experiment, but it was tried at first hastily and without success.

The author, however, was so sure of the nature of the material that he repeated the experiment in company with Mr. Kunz, on Monday, September 11, 1893, in the Tiffany Pavilion of the Mining Building of the World's Columbian Exhibition. A newly planed wheel had been provided, through the courtesy of Messrs. Tiffany & Co., but in order to make the experiment doubly sure a diamond set for cutting was placed in position on the wheel, and left there for a period of five minutes, while the wheel was making twenty-five hundred revolutions per minute. On removing the diamond it was found that there had been no appreciable shattering of the edges by friction, and that it would take a long time for its own powder to be produced in sufficient quantity to have any effect.

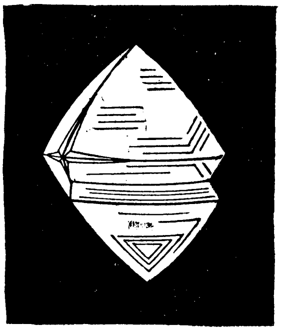

Fig. 2.

The wheel was then charged with the residue from the Cañon Diablo iron, mixed with oil in the usual way. The diamond immediately gave out a sharp hissing sound, making it apparent at once to an expert that the material was cutting, and in a few minutes it was found that a face had been ground down and polished. Two other diamonds were cut and polished in the same way. The last specimen was a complex twin, and when a projecting angle was applied to the wheel the cutting was naturally slow, but none the less effective, and in all respects the residue from the Cañon Diablo iron was found to act exactly like any other diamond powder.

Thus the combined evidence of the author's work with that of Friedel* and Moissan† establishes the fact that the Cañon Diablo iron contains true diamonds, and not any new allotropic form of carbon. It is surprising that crystals are so rare, but, as this paper shows, they do occur.

It has been suggested, since the Cañon Diablo iron has been found in such quantities, that it may have a terrestrial origin, but such an idea is at once dispelled by an examination of the exterior surface of the largest mass thus far obtained, apart from other considerations.

The mass referred to was purchased by Professor J. P. Cooke from Mr. W. W. Howell of Washington, D. C. It weighs 1087 pounds, and is at present in the Harvard Museum. It is seldom that irons which have not been seen to fall retain, at the time they are found, any of the original features of their crust, but this specimen is a marked exception. It is a roughly spherical mass somewhat flattened in one plane. One of these flattened surfaces shows signs of fusion, but is further characterized by deep pittings looking almost like bullet holes, except that it frequently happens that they are larger on the interior than at the orifice. Occasionally they are winding, but all preserve the same general direction. They vary in size from one sixteenth of an inch in diameter to two inches, and reach in some cases a depth of from three to four inches. These cannot be explained by unequal heating or by the erosive action of the air, owing to the fact just mentioned, that they are larger in the interior than at the surface. This character is shown in a reproduction of a small photograph, (Plate I. Fig. 1). The other side of the mass (Plate I. Fig. 2) shows large concave surfaces, as if pieces of six or seven inches in diameter had flaked off, or the hollows had been scooped out by the action of pneumatic drills.

For some time these two utterly different surfaces were a puzzle, but a closer examination disclosed troilite in the depths of some of the small cavities (Plate I. Fig. 1) while on the side of the larger pittings (Plate I. Fig. 2) the same mineral could be seen exposed and

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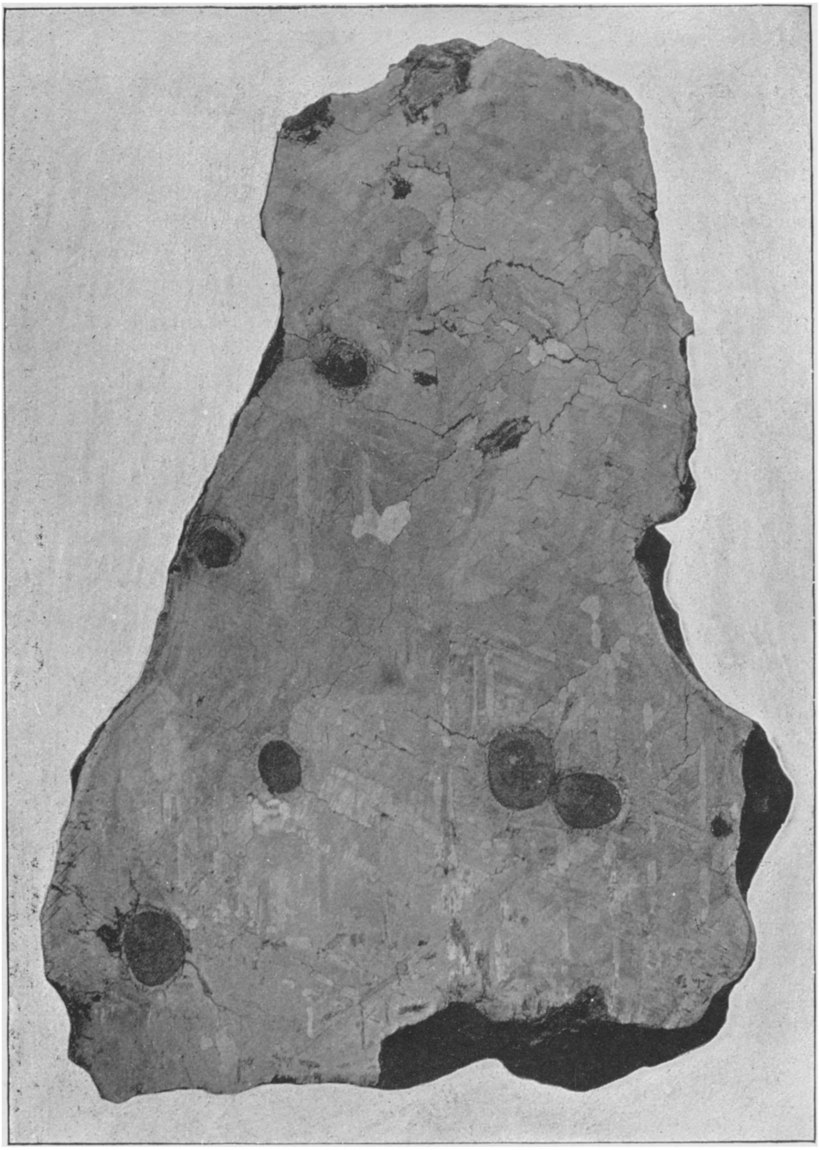
* Bulletin de la Soc. Française de Minéralogie, No. 9, Dec. 9, 1892, p. 258.

† Comptes Rendus, Tome CXVI. No. 7, Feb. 13, 1893, p. 288.



Etched Slab of Cañon Diablo Iron.

unaltered. Evidently, then, the mass must have been a meteorite, moving with its smoother face to the front, and perhaps revolving. In such a case the front would acquire the melted appearance observed, and the troilite nodules would at once fuse and become dissipated, leaving the deep and erratic cavities so characteristic of this iron, while the portion in the rear would acquire the well known pittings due to the flaking off of irregular portions. The iron is largely filled with troilite nodules, and that they did not subsequently weather away is evident from the fact that their cavities appear only on the front of the mass.

The etched surface of the Cañon Diablo iron shows great variation in the distribution of the Widmanstättian figures and troilite nodules, and the occurrence of diamond evidently varies likewise. An etched surface of a slab of this iron presented to the author by Mr. Kunz is shown by a photograph, somewhat less than half the natural size, in Plate II.

A more detailed description of these etched surfaces will appear in a subsequent paper, as the work of isolating and examining the various constituents has not yet been completed.